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DEPARTMENT OF COMMERCE - BUREAU OF MINES

OHIO STATE UNIVERSITY

GRAPHITE

PART I - GENERAL INFORMATION

BY

PAUL M. TYLER

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INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

G R A P H I T E

PART I. GENERAL INFORMATION[1]

By Paul M. Tyler[2]

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DESCRIPTION AND USES

Natural graphite - also known as plumbago or black lead[3] - is a black, lustrous mineral with a greasy feel. It is classed either as crystalline or as amorphous. Since all graphite is crystallized carbon, amorphous graphite is actually not amorphous but cryptocrystalline. Nevertheless, the term "amorphous graphite" is universally applied to all dull, more or less earthy graphite whose particles are so small as to be indistinguishable to the naked eye[4]. Often, even when it can scarcely be differentiated from crystalline graphite, it does contain nongraphitic or truly amorphous carbon. Near Providence, R. I., the same bed is worked for amorphous graphite and for anthracite fuel.

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1 The Bureau of Mines will welcome reprinting of this article but requests that the following footnote acknowledgment be made: "Printed by permission of the Director, U. S. Bureau of Mines. (Not subject to copyright.)"

2 Assistant to Chief, economics branch. The author cordially acknowledges the helpful contributions of Jefferson Middleton of the U. S. Bureau of Mines, author of the recent chapters on Graphite in Mineral Resources of the United States.

3 Less common names are potelot, crayon noir, carbo mineralis, and silver-lead.

4 For classification for customs purposes see Tariff Duties, p. 24.

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Depending upon mode of occurrence and upon the shape of the individual particles, crystalline graphite is further separated into vein (or lump) graphite and flake graphite. Frequently, especially in the British Empire, the three forms of natural graphite are described as (1) plumbago or crystalline graphite (i.e., vein or lump), (2) flake, and (3) amorphous ("black lead"). For commercial reasons, crystalline flake graphite, when the flake is small, is sometimes bought and sold as "amorphous".

Vein graphite has been produced commercially almost exclusively in Ceylon and the flake variety mainly in Madagascar, the United States, and Canada. Madagascar, which did not commence to export graphite until 1908, has now become the leading source of world supply. The better qualities of crystalline graphite, both vein and flake, are used chiefly in the manufacture of crucibles for melting metals (especially steel and brass) and to some extent for ladle stoppers and for the large retorts used for recovering secondary zinc from galvanizers' dross and other wastes. A growing quantity of flake graphite is used in electric dry cells. The poorer qualities of crystalline graphite, including the dust and smaller particles produced in refining and working up the costlier grades, are employed in lubricants, paints, stove polish, foundry facings, and boiler compounds and for sundry minor purposes.

Amorphous graphite, which is produced in Czechoslovakia, Austria, Mexico, Chosen (Korea), Italy, and the United States, is used for foundry facings, paints, lubricants, stove polish, commutator brushes, dry batteries, pencils, and powder glazing crayons.

Artificial or manufactured graphite, although mostly made up into finished electrodes, is also produced in finely divided form so that it competes actively in most of its applications, except perhaps stove polish, with natural amorphous graphite. It is also used extensively in dry batteries. It is made in electric furnaces from anthracite or from petroleum coke.

From time to time proposals have been made to recover graphite from kish. This mixture consisting of graphite, slag, iron oxide and sundry other impurities, separates from molten pig iron in the process of cooling and often accumulates in appreciable quantities at foundries and steel works and ferrosilicon furnaces, though not in sufficient amounts to promise the establishment of an industry that would compete extensively with the production of natural graphite.[5] Carbon, more or less graphitized, is a by-product of several electrochemical processes; under certain circumstances such material may be substituted for natural amorphous graphite.

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5 United States patents for the recovery of graphite from kish have been issued to F. W. Weisman (No. 1239992) and to E. C. Ewen (No. 1271146), and a little graphite has been obtained commercially in the United States from this material which ordinarily contains 8 to 10 per cent graphite carbon in the form of a light, fluffy flake. In Germany, graphite obtained from kish during the war was used in lubricants.

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Chemically, graphite is pure carbon, but physically it differs markedly from the diamond or charcoal, the other two allotropic forms of the same element. The diamond is the hardest mineral, but graphite is one of the softest (hardness =1 it is opaque, black, extremely resistant to the action of acids or heat (almost incombustible at temperatures below about 700° C.), and a good conductor of both heat and electricity. The specific gravity is 2.1 to 2.3, which is intermediate between that of charcoal (1.3 to 1.9) and that of the diamond (3.5).

Chemical Properties

The chemical behavior of the various forms of graphite has been described by Spence:[6]

> "Chemically, a ready means of differentiating between the three forms is to treat with potassium chlorate and concentrated nitric acid in the proportion of one part of the substance to be tested, three parts of pottassium chlorate and sufficient acid to render the mass liquid. The mixture is then heated on a water bath for several days, when the diamond is found to be entirely unaffected. The graphite is converted into golden-yellow flakes of graphitic acid and the amorphous carbon is altered to a brown substance soluble in water."[7]

He notes, however, that

> "Many so-called graphites, when treated in this way, are shown to be charcoal, natural coke, or even coal or carbonaceous shale. Coal or carbonaceous shale may be detected by the amount of volatile matter present, while all of the enumerated adulterants are conspicuous by reason of their low ignition temperatures, as compared with graphite. A further means of distinguishing between graphite and coke or retort carbon is to note their behaviour when fused with sodium sulphite: graphite does not reduce this salt, whereas coke and retort carbon react very actively with it.
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> * * * * * *
>
> "It was formerly suggested that several varieties of graphite existed, the distinction between them being based on their different behaviour when treated with chemicals. For instance, certain graphites, when moistened with fuming nitric acid and then heated, swell up and

6 Spence, Hugh S., Graphite: Canada Dept. Mines, Mines Branch, Rept. 511, p. 4 and pp. 7-8.

7 "Donath (Der Graphit, p. 3) considers it not absolutely certain that chemically pure amorphous carbon yields a red-brown solution when treated as described, but suggests that the coloration may be due to impurities in the material."

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assume vermiform shapes, having a circumference of ¼" to ½" and a length sometimes of several inches. These forms have a steel grey colour and metallic lustre, and are bent and twisted in regular curves: their regular structure imparts to them a very characteristic appearance, and the volume of such so called "graphite worms" is often a hundred or more times greater than that of the original graphite from which they were formed. It is supposed that the cause of this phenomenon is the capillary structure of the flakes, which permits them to absorb the acid readily. On heating, the gas generated from the acid exfoliates the graphite. The graphites that yield such forms are, therefore, not believed to be essentially distinct from those that show no such reaction. The former ware originally classed by Luzi, who investigated many graphites along these lines, as true "graphites", while the latter he termed "graphitites". The name "graphitoid", also, has been applied to a black, earthy pigment containing nitrogen and water, which burns in the Bunsen flame, and which even under the highest power of the microscope exhibits no crystalline structure.

"Weinschenk, who made an investigation of many graphites, disputes the existence of any such distinct modifications of natural graphite, and regards the different behaviour of the graphites from various localities as due usually to their structure. The above distinctions are seldom made nowadays, and the matter of these differences of behaviour under certain conditions possesses only academic and little technical importance. The nitric acid treatment has, however, been employed as means of cleaning natural graphite and obtaining a product of exceptional purity and in a very fine state of division.

"When finely powdered graphite is heated with a mixture of one part of nitric and four parts of strong sulphuric acid, or when a mixture of fourteen parts of graphite and one part of potassium chlorate is warmed with seventy-eight parts of strong sulphuric acid, the graphite assumes a purple tint, but on washing regains its original colour. It is, however, no longer graphite, but contains in addition oxygen, hydrogen, and sulphuric acid. When this is heated to redness it swells up with a copious evolution of gas and then falls to an extremely fine powder of pure graphite, which has a specific gravity of 2.25 - (so-called "Brodie's graphite").

"The above process has been employed for the purpose of purifying natural graphite. With this object it is first ground fine and the powder well washed in troughs to remove as much of the earthy gangue as possible. The concentrates are then treated as described above and the resulting material passed on to the surface of water, when the graphite floats off and the impurities sink. Flake graphite is more readily purified by this process than the powdery forms. The latter may be similarly treated, however, if a small amount of sodium fluoride be added to the mixture as soon as the evolution of chlorine in trioxide gas has ceased; by this means, the silica is removed as silicon tetrafluoride.

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"Artificial graphite, the product of the electric furnace, does not possess the property of swelling up when treated with nitric acid, but that separating out from fluid metals, by reason either of simply the high temperature or on account of chemical reaction, possesses it very markedly.

"Artificial graphite may be either amorphous or crystalline. Its specific gravity ranges from 2 to 2.25, and its temperature of combustion in oxygen is in the neighbourhood of 660° C. The resistance to oxidation of artificial graphite produced in the electric furnace is proportional to the temperature at which it was formed.

"Ceylon graphite, which is more or less readily oxidized, may be made more refractory by subjecting it to great heat."

HISTORY

Graphite was used as a coloring agent in the earliest times, but its identity was not recognized until the end of the eighteenth century, and its commercial development did not become extensive until near the close of the nineteenth century. The names "black lead" and "plumbago" both record the idea that prevailed throughout the Middle Ages that graphite was a form of lead or at least contained that metal. Heinrich Pott (1692-1777), a German chemist, reported that "plumbago" contained no lead, but there is some doubt whether he actually experimented with graphite or with molybdenite, which it so closely resembles. Karl Wilhelm Scheele (1742-1786), the famous Swedish apothecary, seems to have been the first to demonstrate the difference between plumbago and molybdenite, and the name "graphite" was first given to the mineral by H. G. Werner, the pioneer German teacher of scientific mineralogy, in 1789.

At the beginning of the fifteenth century crucibles made from Bavarian graphite were used by the alchemists, and the Borrowdale mines in Cumberland, England, began furnishing pencil graphite of excellent quality in 1554.

A method for making artificial graphite was patented by Girard and Street in 1893; but the commercial method, an adaptation of the carborundum process, was patented by E. G. Acheson in 1896. The first production was by the Acheson Graphite Co. in 1897.

Being international in character, the graphite industry was violently disturbed by the World War. Difficulties of shipping and embargoes placed by France and Great Britain to prevent supplies of Madagascar and Ceylon graphite from falling into the hands of the enemy tended to interrupt the normal flow of supplies. This in conjunction with the suddenly expanded demand (intensified by some pyramiding of orders) brought feverish activity and some measure of prosperity to the domestic industry. Following the cessation of hostilities and the consequent stoppage for a time of demand enormous stocks accumulated in various parts of the world, and it was not until about 1923 that these excessive accumulations were sufficiently dispersed to permit the resumption of mining on anything like a normal scale.

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The chief post-war developments within the industry are the increased adoption of the flotation process as an aid to the economical recovery of flake graphite from low-grade deposits and the marked changes in the nature of consumption, changes that have been reflected in the relative competitive position of the leading producers.

MODE OF OCCURRENCE

Vein graphite, as the name indicates, is found in more or less well-defined veins, although it also occurs as pockety accumulations along contacts, particularly those of pegmatites with limestones or schists. Flake graphite, on the other hand, is found disseminated as scaly particles in metamorphic rocks, principally schists and limestones.[8] Whereas vein graphite is prepared for market largely by hand picking, disseminated flake is so interspersed in the containing rock that it can be separated only by mechanical concentration methods. Amorphous graphite usually occurs in the form of metamorphosed coal seams, highly carbonaceous shales, or asphaltic beds. The graphite content of such deposits may be as high as 85 or 90 per cent, whereas domestic deposits of disseminated flake frequently yield only 3 per cent, and the richest deposits of crystalline flake (Madagascar and Canada) rarely contain more than about 40 to 50 per cent of carbon. When it occurs in veins graphite often shows clearly that crystallization proceeded simultaneously from both walls, producing a comb structure. Occasionally, however, one half of a vein consists of foliated graphite and the other of fibrous graphite.

Although usually found in metamorphic rocks and to a much more limited extent in igneous rocks graphite has also been found in unaltered sediments[9] derived from the decay of nearby graphitic rocks, although such deposits can not be considered of commercial importance because the graphite scales, being soft, are mostly destroyed in the process of sedimentation.

ORIGIN

All graphite was formerly thought to be of organic origin; even that found in certain granites was said to have come from partly digested fragments of nearby sedimentary rock. In Maine there is a pegmatite containing 9 per cent of graphite, mostly in evenly distributed flake but with a few nests of pure graphite, 1 inch in diameter, which separated out later than the quartz but earlier than the feldspar. Somewhat similar dikes carrying graphite as an original constituent are known in New York and elsewhere. Some veins of graphite have been attributed to pneumatolytic processes, being formed by the condensation of carbon vapors (possibly derived from neighboring carbonaceous sediments) penetrating fractures in the rocks during metamorphism. Graphite, however, is found in meteorites, and since an organic origin is difficult of conception likewise in the case of certain well-known deposits in igneous rocks, geologists now generally agree that graphite may be of inorganic as well as of organic origin, although the mode of origin of numerous specific deposits is still a matter of controversy.

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8 In schists and quartzites the flakes generally are disposed parallel, conformably with the schistosity, but in limestones and in some gneisses they show no uniform arrangement.

9 Emerson, B. K., Geology of Old Hampshire County, Mass., Comprising Franklin, Hampshire, and Hampden Counties: U.S. Geol. Survey Monograph 29, 1898, p.365.

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Tests by Bastin on quartz associated with graphite obtained from Lead Hill, near Ticonderoga, N. Y., appear to indicate that graphite has been formed, in some deposits at least, at temperatures below 575° C., that is, at temperatures greatly below those at which it is produced artificially in the electric furnace (over 2000° C.).[10]

PROSPECTING AND DEVELOPMENT

Many of the numerous failures in the graphite industry have been attributable to lack of knowledge of the size and shape of the ore bodies. Flake graphite commonly occurs in rocks that have been intensively squeezed and folded, and often the intrusive dikes that contributed to the formation of the graphite are found to cut it off unexpectedly. Moreover, the richest ore naturally occurs in streaks or lenslike bodies that merge more or less gradually into leaner material that may or may not be ore. In the case of many American deposits the depth of weathering introduces another variable, the unaltered rock being frequently too hard to treat economically. Variations in the content of deleterious gangue minerals, notably mica, may also affect successful exploitation.

Under the circumstances it is clearly impossible in many instances to ascertain whether a given deposit is extensive enough to justify the building of a mill without first spending a considerable amount of money on prospecting. Surface indications and even underground work often fail to reveal the needful information. Nevertheless, mill after mill has been put up both in the United States and Canada the moment a little trenching aroused the hopes of the operators. Very rarely has any true development work been performed much in advance of actual mining. About 1918, however, several Canadian properties were systematically explored by diamond drilling, which in most cases appears to be the only reliable way to prove up a deposit beforehand. Churn drilling is another means of development, but it must be carefully done. Unless the casing is always kept down near the bottom of the hole disintegrated material abraded from an upper bed is likely to be washed down into the cuttings and may lead to an exaggerated idea as to the actual thickness of the graphite-bearing strata. Under such circumstances it would appear safer to sink an occasional test pit to check the drill-hole records. Field work by the Radiore Co. has demonstrated that its methods furnish information with regard to the size as well as the location of graphitic material; even disseminated flake deposits are conductive.

In addition to determining the size of the ore body the operator or investor should pay attention to the nature of the material. It should be remembered that it is not so much the percentage of total graphite that is important as it is the percentage that can be recovered in the form of a salable product. Among other things, therefore, a study must be made of the physical nature (e.g. size and toughness) of the graphite particles and of the amount of mica, pyrite, and other undesirable impurities present. Limestone deposits in particular generally look better than they really are.

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10 Bastin, Edson S., Origin of Certain Adirondack Graphite Deposits: Econ. Geol. vol. 5, 1910, pp. 134-157.

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MINING METHODS

Most graphite mines are merely small, shallow pits. In Alabama the rather thin overburden is first removed by means of plows and scrapers or wheelbarrows, and the soft weathered ore is then attacked with picks and crowbars. Ordinarily it must be loosened with black powder; the holes are drilled mostly with hand "jumper" drills and are occasionally chambered with dynamite. In Texas 5½-inch holes are drilled by a Keystone wood-fired churn drill at the corners of 12-foot squares and loaded with 60 per cent dynamite. In Canada, likewise, the early workings were all open pits, started in the most favorable outcrops and following the ore. At some of the larger pits, which are in hard rock and never as much as 100 feet deep, hoisting was done by derricks.

Underground mines, whether opened by shafts or tunnels, are generally worked by room-and-pillar methods. In pitching deposits the underground workings are likely to be merely a continuation of an open cut starting from a point where the cover of waste rock becomes excessively deep.

CONCENTRATING AND REFINING

Since flake graphite is invariably associated with a high percentage of gangue material it must always be subjected to a cleaning process to prepare it for use in consuming industries. Amorphous graphite, on the other hand, can often be mined pure enough so that it needs at most to be only roughly sorted to bring it to merchantable grade.[11] At the Ceylon mines vein graphite in the lump sizes is removed and polished by hand, the larger pieces being broken by hatchets. The smaller sizes are cleaned by primitive methods (including hand picking, panning, and winnowing) which are made commercially possible only because the ore is high-grade and labor is both abundant and cheap.

The economical recovery of flake graphite from disseminated ore has proved one of the most baffling problems in modern ore-dressing practice. Ordinary gravity methods of concentration are handicapped by the fact that quartz, feldspar calcite, mica, and other associated minerals differ little in specific gravity from graphite. The average specific gravity of graphite is 2.2, while that of the containing gangue is ordinarily about 2.6. Being lighter the concentrate appears on most machines where the tailings ordinarily come and vice versa. Moreover, mica, a very common associate, has other properties (including form, hardness, and toughness) almost identical with those of graphite. A source of mechanical trouble is the adherence of the graphite to pulleys and belts, making them slip. Added to these difficulties crucible makers, who have been the most profitable market, have demanded a purity of 90 per cent or better and have refused to accept material finer than 80 or 90 mesh. To meet these rather rigid requirements various processes have been devised, but prior to the successful introduction of oil flotation practically all of them were complicated and expensive and at the same time yielded only a poor recovery. It has been estimated that the average loss in the graphite mills of Canada and the United States has been not less than 50 per cent of the graphite contained in the ore treated.[12] Very often it has been much greater.

11 Apparently the only concentrating plants for amorphous graphite are in Italy.

12 Spence, Hugh S., Ref. cited (see footnote 6).

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As concentrating practice at American mills in 1917 has been described in detail by Dub[13] and again by Spence[14], who likewise furnished similar data with respect to Canadian mills, there is no need to repeat the same information in this discussion, more especially because most of these mills have since been abandoned or rebuilt; in fact, several of them never were operated successfully. It may be helpful, however, to review briefly the more important processes, both wet and dry, that have been adopted for the recovery of graphite.

The beneficiation of graphite ores usually is conducted in two stages, first producing a rough concentrate and then refining this concentrate to produce one or more finished products. For final finishing the buhr mill has been almost universally used.[15] It separates the flakes into their constituent laminations and at the same time grinds the adhering sand so that it can be eliminated by screening. When the proportion of hard particles is too great, however, grinding in a buhr mill materially reduced the size of the flake; and at the same time the impurities are more likely to become imbedded in the graphite flake so that they can not be readily removed. This latter tendency, commonly described as pancaking, is a serious cause of high silica in finished graphite and is the reason for the general rule in graphite milling to eliminate as much impurity as possible between each successive step in the beneficiation. Certain preliminary processes, mostly dry methods, are often installed in the finishing mills to improve the rough concentrate preparatory to sending it to the buhr mill. Such processes may or may not be classed as part of the actual refining operation.

Of the various methods for rough concentration, seven may be classed as more or less distinct and different in principle, the first four being wet processes and the last three dry,-

1. Standard gravity methods, such as jigs, tables and buddles.
2. Log washer process.
3. Water-skin flotation.
4. Oil-froth flotation.
5. Graded crushing and screening.
6. Pneumatic processes.
7. Electrostatic separation.

Screening forms an important intermediate process in almost all installations and at times becomes itself the main process. The latter was true in Canada, where the dry process came into especial prominence between 1906 and 1912, during which period it was installed in nine mills. In these mills the operations consisted of repeated crushing in rolls of the flour mill type with screening between successive crushing operations. Occasionally dry tables were also used. Even when combined with pneumatic jigs and tables the purely mechanical dry processes have not as a rule been commercially successful. They call for a large mill with much floor space, high-power consumption, and frequent handling. All this means high costs, and since usually neither the recovery nor the grade of flake has proved satisfactory failure has been the almost universal result. Electrostatic separation, though possessing many of the inherent disadvantages of the purely mechanical dry processes, has been moderately successful in several different localities.

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13 Dub, G. D., and Moses, F. G., Mining and Preparing Domestic Graphite for Crucible Use: Bull. 112, Bureau of Mines, 1920, 80 pp.

14 See footnote 6.

15 In some cases rolls have been substituted for buhr stones, but usually the results have proved inferior.

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Among the various wet processes log washers (and likewise rake washers similar to the Dorr classifier) have proved satisfactory, kerosene oil being sometimes added to the feed. Frequently the tailings from one washer pass to another, possibly after further crushing, and again the overflow may be sent to shaking tables. The various water skin-flotation processes have all been based in principle on the greasy nature of graphite, combined with the surface tension of liquids. Various plans have been devised for drying and occasionally oiling the flake and of feeding the pulp at the proper angle and velocity upon the surface so that the graphite will float and the impurities will sink. Some of the home-made devices have worked fairly well, just as among dry processes home-made air classifiers have given better results than commercial machines, particularly when operated by the inventors.

Before the advent of froth flotation simple home-made buddles, although one of the earliest methods for concentrating graphite, seem generally to have yielded the best results. Several mills installed more complicated equipment, but later returned to the use of buddles. In turn, however, these have recently given way to modern flotation machines. One of the latest installations is in California at a property that had hever been operated profitably by using the older methods of operation. The flow sheet of this mill is essentially as follows:[16]

1. Ore from grizzly.
2. Jawbreaker (2 inch).
3. 4 by 4 ft. ball mill in closed circuit with
4. Akins classifier. Overflow to
5. Three K. & K. flotation machines in series. Concentrate cleaned on
6. Home-made cell of Callow type. Cleaned concentrate to
7. Wilfley tables to remove iron and coarse gangue and then to
8. Pump to
9. Oliver filter, 4 by 3 ft. Thence to
10. Two rotary driers. Partly nodulized product reground in
11. Ball mill 3 by 6 ft. loaded with slugs. After cooling to
12. Two bolting machines in parallel producing 13 and 14.
13. Undersize (dust) sold as foundry facings.
14. Oversize treated on Cottrell suction screen.
15. Flake products on 60, 100, 150, and 200 mesh.
16. Bag-house dust sold as paint material.

The K. & K. system of flotation has been adopted at Burnet, Tex., being used in this installation both for roughing and cleaning. This is the third mill on the property. The first utilized air separation and the second, electrostatic separation. The Huff electrostatic machines have been retained for further cleaning the concentrates after they have been dried, but it has been found unnecessary to use them. The recoveries are reasonably good but vary considerably according to the fineness to which the product can be ground and the grade of concentrate that can be sold.[17]

16 Hubler, W. G., Concentrating Graphite in Southern California: Eng. Min. Jour., vol. 125, June 30, 1928, p. 1059.

17 Menardi, H. B., Modern Flotation Plant for Graphite: Rock Products, vol. 31, No. 18, Sept. 1, 1928, pp. 74-7.

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CHEMICAL REFINING OF GRAPHITE

Owing to the difficulties of mechanical concentration various schemes have been proposed for the chemical preparation of a pure product from natural graphite. For most commercial purposes 90 per cent graphitic carbon content is pure enough; in fact, a much lower grade product is usually acceptable. Now that flotation has been successfully introduced and the technique of refining has been improved the required purity can ordinarily be obtained more cheaply now by mechanical methods. Furthermore, for such special purposes as require a higher purity artificial graphite approaching practically pure carbon is available. For these reasons chemical refining processes have been largely dispensed with although they are being considered again for removing the silica present between the laminae of Alabama flake.

Of the various processes that have been employed commerically the greater part relate merely to the removal of silicate impurities by fusing (usually with sodium carbonate), by leaching with hydrochloric or hydrofluoric acid, or by a combination of these two treatments.[18] By Laine's process, patented in France, the ash content of low-grade Madagascar flake can be reduced from 40 to only 1½ per cent. After washing with dilute acid the material is fused with sodium carbonate, leached first with water and then with acid, and finally washed with water.

In Luzi's process, which was virtually mechanical, the graphite, after being moistened with concentrated nitric acid and then ignited, exfoliates, thereby releasing the impurities between the laminae so that they can be readily washed out

Brodie's process produces a very finely divided rather than an especially pure graphite. Powdered graphite is mixed with one-fourteenth of its weight of potassium chlorate, stirred in an iron vessel with twice its weight of concentrated sulphuric acid, and heated on a water bath until action ceases. After cooling the residue is washed in water, dried, and heated to a red heat, whereupon the graphite swells and crumbles into an extremely fine powder, which if necessary can be further cleaned by elutriation; or sodium fluoride may be added. Pritchard produces the same result but varies the proportions of the chemicals somewhat.

Bessell Bros. patented an interesting process in Germany in 1887 which seem to be a forerunner of the modern oil-flotation processes. They mixed graphite with 1 to 10 per cent of petroleum, benzine, fat, or wax and stirred the mixture into water to which small amounts of dilute acid and chalk were added to generate a current of gas. By this method a product containing 90 per cent of carbon could be floated out of 40 per cent material.

According to a process devised by Charles W. Woodruff of Columbus, Ohio, for purifying Mexican amorphous graphite, the finely ground ore trickles downward over baffles placed in a cylinder 22 feet high. Hydrogen fluoride, passing upward countercurrent to the ore, removes the silica as a gas (silicon tetrafluoride) which is passed through water, forming hydroflosilicic acid and gelatinous silica. The hydrogen fluoride is generated by heating fluorspar and sulphuric acid, the residue of calcium sulphate being suitable for sale as satin white to paper makers.

18 Several of such methods are described by Spence (see footnote 6), pp. 112-13.

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MANUFACTURE OF ARTIFICIAL GRAPHITE

In the United States graphite is made artificially on a very large scale by the Acheson Graphite Co. This concern, controlled since 1927 through stock ownership by the Union Carbon & Carbide interests, is the pioneer producer; it was founded by Dr. Edward Acheson, who in 1896 invented the first successful commercial process. For many years the United States remained the sole producer of artificial graphite, but later the same company began making its products in Canada and now artificial graphite is also made by similar methods by Lonza-Werke in Switzerland; Le Carbone and the Société générale d'électricité in France; Siemens & Conradty in Germany; and various works in Czechoslovakia, Italy, and elsewhere.[19]

The story goes that Dr. Acheson discovered the process for making carborundum (silicon carbide) while searching for a method of producing graphite and that he actually made graphite first as a by-product from the production of carborundum on a commercial scale. This story emphasizes the essentials of the process for it apparently depends upon the production first of a carbide (of silicon, iron, aluminum, calcium, etc.) which then breaks down to form graphite. Pure amorphous carbon can not be made into graphite, at least by this process. Anthracite -- even anthracite waste or culm -- has proved the most suitable material for producing graphite in bulk because it contains the requisite amount of impurities already disseminated through it. About 2 or 3 per cent of iron ore is usually added, but even then the quantity of ash is seldom over 10 per cent. Apparently the metals as they dissociate from their carbides are volatilized and form carbides again, the process being repeated until the carbon is all converted into graphite and the impurities are all volatilized.

The graphite furnace is similar to that used in the production of carborundum, though usually somewhat smaller. It consists of a long trough lined with carborundum and having two electrodes, one at each end. The anthracite, ground to about the size of rice, is charged into the trough, and since it is a poor conductor when cold a core of carbon rods is provided to carry the current until sufficient heat is generated to start the reaction. A furnace 30 feet long and taking a charge 20 by 14 inches in cross section will consume 800 kw. As the coal becomes graphitized the conductivity of the charge increases and the voltage is reduced.[20] In its passage through the charge the electric current forms innumerable small arcs, and the whole mass becomes incandescent. The temperature is very high, probably in the neighborhood of 7500° F. The furnaces are constructed with heavy end walls, but the sides and top are taken out after each bath is completed. The time required depends upon the purity of the raw material and upon the degree of purity desired in the product. For powdery graphite the usual cycle is five days, 12 to 24 hours being required for heating and about four days for cooling, tearing down, and reloading. The firing of electrodes takes longer.

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19 Ryschkewitsch, Eugen, Graphit: Charakteristik, Erzeugung, Verarbeitung, und Verwendung, Leipzig, 1926.

20 In making graphitized electrodes the current at the start is 3000 amperes at 220 volts, increasing to 9000 amperes at 80 volts at the end.

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After the current is cut off the sand and coke cover is removed, exposing a layer of carbide that forms directly over the graphite. At this stage the furnace is still quite hot. After it cools off the carborundum is removed as a by-product, and the graphite is taken out and ground for the various purposes for which it is required.

The electrode furnace is similar to the graphite furnace, except that the electrodes are placed crossways in the furnace to maintain the electrical resistance. Rectangular electrodes are stood on end, while round rods are piled like cord wood. The carbon or petroleum coke is first finely powdered and then intimately mixed with pitch, a small quantity of iron ore or other carbide-forming substance being added at the same time. The mixture is then warmed and fed to a press, which forms the rods by extruding them through holes of the desired shape and size. Molded electrodes are also made, but extruded electrodes are considered superior, especially for electrolytic work. Before graphitizing the electrode blanks must be dried and baked, an operation consuming 10 to 20 days and requiring careful inspection and control because various defects may make their appearance at this stage. After baking the rods are ready to be graphitized. The floor of the furnace is covered with a thin layer of pulverized coal, and the spaces between the electrodes are filled with ground coke around which is placed an insulating layer of sand and coke. The graphitizing process is the same as in the production of powdery graphite but, according to Mantell[21] the furnace cycle takes at least 25 and somtimes as much as 40 days.

The French process for making electrodes differs from the Acheson process, in that it is continuous. Graphitization takes place in an arc which plays within a chamber cut from a block of solid coal or carbon. The raw electrode is fed into one end of this chamber by rollers, and it passes out the other end as a graphitized product.

For lubricating purposes pure-grade artificial graphite is ground to 200-mesh and then deflocculated so that it can be suspended in oil or water. According to Doctor Acheson[22] deflocculation is accomplished by treating the finely ground graphite with a water solution of tannin, the amount of tannin being 3 to 6 per cent by weight of the graphite treated. The results are much more pronounced if the mixture has been pugged for a considerable time, even for as much as one month. Ammonia hastens the operation, whereas carbon dioxide will prevent it. Eventually an intensively black liquid is obtained, consisting of water, a small amount of tannin, and graphite, the graphite being now in a state of colloidal subdivision that Doctor Acheson describes as molecular. This graphite can be flocculated by the addition of a very minute amount of hydrochloric acid but even after flocculation its particles are so fine that it can be dried into a solid mass like a sun-dried clod of clay.

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21 Mantell, C. L., Industrial Carbon: New York, 1928, p. 38.
22 Acheson, E. G., Deflocculated Graphite, Jour. Franklin Inst., vol. 164, 1907, p. 376.

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Deflocculated graphite is prepared for practical use by first forming a paste consisting of 50 per cent graphite and 50 per cent water. This paste is ground in oil until eventually the water is completely replaced by oil mixed with kerosene. This paste yields the Acheson lubricating product "Oildag." A mixture of water with the paste of graphite and water is termed "Aquadag." "Gredag" is a mixture of finely divided graphite and heavy grease.

Kryptol, a granular material employed as a resistor in electric heaters and furnaces, is said to consist of a mixture of graphite, probably artificial graphite, and amorphous carbon.

WORLD PRODUCTION OF GRAPHITE

Statistics on the world's annual output of graphite, which are fairly complete, indicate a gradual increase from 97,673 short tons, valued at $2,784,978, in 1903 to about 150,464 short tons, valued at $4,756,553, in 1913. The increase in the average unit value from $28.51 to $31.61 is explained largely by higher prices obtained for Ceylon exports, which advanced in value during the period from $72.25 to $91.82 per short ton. The inclusion in former years of the output of low-grade Georgia schists used for coloring fertilizers, which were subsequently eliminated from the statistics, also contributed to the same result. The average value for all countries exclusive of Ceylon and the United States increased only from $11.71 in 1903 to $13.43 per ton in 1913.

As a result of the World War production was stimulated in almost all countries, with the result that in 1917 a maximum total of about 240,000 short tons was attained. Congestion of stocks following the war drastically reduced production even in the older producing areas, and the world output fell far below pre-war levels, reaching a minimum of less than 100,000 short tons in 1921, after which it rose slowly. For the 10 years ending in 1913 the average output per year was 123,571 short tons, of which 40,233 tons was crystalline and 83.338 tons was amorphous graphite.

In 1903, Austria, Ceylon and the United States furnished 80 per cent of the world output. In 1913 Austria (including Bohemia) and Ceylon furnished about 60 per cent of the total tonnage. By that time the output of Georgia shales no longer appeared in the statistics, and the United States had become a minor producer, the remainder of the world output coming principally from Germany, Italy, Chosen, and the newly opened fields in Madagascar. As the industry gradually recovers from the world-wide collapse that followed the armistice the new alignment is much as it was in 1913, except that Madagascar has gained while Ceylon has lost. Due to the high quality of its product, Ceylon, although contributing only about one-fifth of the actual tonnage, alone accounted for almost two-thirds of the value in the last pre-war year. Since the war Ceylon has never recovered its former position. This failure is due partly to the reduced demand for graphite crucibles, for the manufacture of which Ceylon plumbago had been generally preferred, and partly to competition from Madagascar.

Ceylon is the leading producer of vein graphite and Madagascar of flake graphite, the balance of crystalline flake being derived almost wholly from the United States and Canada. For amorphous graphite, Austria and Czechoslovakia produce the principal quantity. Korea is next in importance, followed by Germany, Italy, Mexico and the United States.

The various changes in sources of world supply are indicated in the following table, which gives the available data for selected years.

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World production of natural graphite, 1903, 1913, and 1918-27, in metric tons

	1903	1913	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927
Australia	- - -	- - -	208	102	54	- - -	51	- - -	3	- - -	- - -	10
Austria	29,597	1/49,457	1/44,770	8,265	11,543	13,280	14,034	9,403	9,523	13,079	14,756	18,058
Brazil	- - -	3	45	2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Canada 2/	661	1,961	2,826	1,234	1,987	850	542	1,010	1,210	2,331	2,474	1,659
Ceylon 3/	24,491	28,996	15,701	6,779	9,353	4,419	11,024	10,840	9,806	15,674	11,810	13,091
Chosen 3/		14,543	13,659	12,945	18,228	8,002	19,330	13,576	16,032	15,040	18,692	17,942
Czechoslovakia	(4/)	(1/)(4/)	(1/)(4/)	31,234	22,925	13,522	10,500	9,873	11,935	18,466	30,818	41,113
Finland	- - -	- - -	- - -	30	27	- - -	- - -	- - -	- - -	- - -	- - -	- - -
France	126	1,194	2,132	650	272	1,100	- - -	190	514	1,139	855	900
Germany	3,720	12,057	64,080	30,525	20,639	24,565	32,342	20,856	10,079	16,853	14,304	17,773
Greenland	(7/)	(7/)	(7/)	(7/)	5/1,380	2,000	432	6/ 60	6/ 53	6/ 32	- - -	- - -
India (British)	- - -	- - -	82	129	102	25	20	- - -	- - -	- - -	- - -	- - -
Indo-China	(7/)	(7/)	3/15,000	3/7,451	- - -	- - -	- - -	- - -	2,264	6/221	6/815	6/410
Italy	7,922	11,145	11,653	7,626	5,398	5,233	4,546	5,691	7,740	9,937	9,605	7,300
Japan	114	667	1,886	1,954	1,133	900	1,046	801	767	1,010	498	633
Madagascar 3/	(7/)	7,997	16,000	4,983	14,425	6,220	6,675	10,768	11,556	14,980	11,454	14,329
Mexico (amorphous)	1,405	4,023	5,080	4,023	2,992	2,911	2,054	5,489	8,023	6,264	4,435	5,837
Norway	- - -	- - -	- - -	- - -	10	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Russia	(7/)	1,983	525	1,100	- - -	1,700	- - -		8/169	8/1,298	8/5,207	(7/)
Spain	- - -	- - -	710	1,958	6,315	2,772	530	- - -	- - -	1,945	603	352
Sweden	25	88	102	- - -	7	- - -	- - -	- - -	- - -	- - -	- - -	- - -
Union of So. Af.		35	72	78	66	9/297	38	54	50	47	46	58
United States												
Amorphous	10/15,055	2,035	5,951	3,065	4,258	1,671	1,996	3,680	3,693	3,208	2,699	2,354
Cryatalline	2,059	2,297	5,834	3,668	4,369	540	839	1,798	816	1,024	2,263	2,370

1/Including the following quantities produced in the provinces of Bohemia and Moravia, now a part of Czechoslovakia: 1913, 32,175 tons; 1918, 27,355 tons. 2/Shipments. 3/Exports. 4/Included under Austria. 5/Estimated. 6/Concentrates. 7/Data not available. 8/Year ended Sept. 30. 9/Includes 254 tons from Kenya Colony. 10/Includes large quantities of graphitic shale from Georgia (no longer classed as "graphite").

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WORLD CONSUMPTION OF GRAPHITE

Germany has ordinarily been the largest consumer of graphite, importing in 1913 about 41,000 short tons (about one-half of which came from Austria) and producing more than 13,000 short tons within its own borders. The manufacture of lead pencils took about 4 per cent of the pre-war consumption, crucibles and foundry uses accounted for 36 per cent, and stove polishes and paints required 30 per cent. The remainder was used chiefly in dry lubricants.[23] The United States used normally about 30,000 short tons annually and is the second largest consumer, followed by the United Kingdom, which in 1913 imported over 23,000 short tons, mainly from Ceylon, Madagascar, and Japan. Austria-Hungary, one of the largest producers before the war, was also a large consumer, using about one-half of its own production of low-grade amorphous material and in addition requiring moderate quantities of Ceylon, Madagascar and Mexican graphite for its important crucible and pencil manufacturing industries. As a whole this business, though divided up among several of the succession states of the former Empire seems to have suffered little from the political readjustments. Due in part to the rapid increase in production by its Madagascar colony and in part to the expansion in its steel industry, France has become a more important factor in the graphite situation than she was in 1913. Even in 1920 and 1921, during the depression, France imported twice as much as before the war, when yearly imports averaged less than 4,000 tons. Italy is the only other important consuming country at the present time.

DOMESTIC PRODUCTION

Natural Graphite

Except for a period of about eight years during and after the Great War, the annual production of crystalline graphite in the United States has remained remarkably uniform since 1900. After eliminating from the statistics the output of low-grade graphitic shales in Georgia, which were for some years included in the statistics as graphite, the same may be said in general of the domestic output of amorphous graphite. In recent years the total American production of both kinds of material has remained in the neighborhood of 5,000 short tons annually and has been about evenly divided between the two varieties. Available statistics for the output of both crystalline and amorphous graphite in the United States are given in the following table:

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23 Raw Materials and Substitutes in the German Mineral Industry: Min. Jour. (London), vol. 123, Oct. 5, 1918, p. 577.

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Natural Graphite - Production in the United States[1]

(Domestic natural graphite sold or used by producers)

Year	Amorphous		Crystalline		Total	
	Quantity (short tons)	Value	Quantity (short tons)	Value	Quantity (short tons)	Value
1901	809	2/	1,984	2/	2,793	$ 167,714
1902	4,739	2/	1,968	2/	6,707	182,108
1903	16,591	2/	2,269	2/	18,860	225,554
1904	16,927	82,925	2,841	238,447	19,768	321,372
1905	21,953	80,639	3,018	237,572	24,971	318,211
1906	16,853	102,175	2,944	238,064	19,797	340,239
1907	26,803	125,821	2,474	171,149	29,277	296,970
1908	1,443	75,250	1,144	132,840	2,587	208,090
1909	5,096	32,238	3,147	313,271	8,243	345,509
1910	1,407	39,710	2,795	295,733	4,202	335,443
1911	1,223	32,415	2,395	256,050	3,618	288,465
1912	2,063	32,894	1,772	187,689	3,835	220,583
1913	2,243	39,428	2,532	254,328	4,775	293,756
1914	1,725	38,750	2,610	285,368	4,335	324,118
1915	1,181	12,358	3,537	417,273	4,718	429,631
1916	2,622	20,723	5,466	914,748	8,088	935,471
1917	8,301	73,481	5,292	1,094,398	13,593	1,167,879
1918	6,560	69,455	6,431	1,454,799	12,991	1,524,254
1919	3,379	47,716	4,043	731,141	7,422	778,857
1920	4,694	49,758	4,816	576,444	9,510	626,202
1921	1,842	20,860	595	75,664	2,437	96,524
1922	2,200	3/	925	85,242	3,125	3/
1923	4,056	39,560	1,982	151,434	6,038	190,994
1924	4,071	38,533	900	48,977	4,971	87,510
1925	3,536	39,640	1,129	56,721	4,665	96,361
1926	2,975	40,500	2,495	178,842	5,470	219,342
1927	2,595	35,850	2,612	197,121	5,207	232,971

1/ From Mineral Resources of the United States.
2/ Not given separately.
3/ Value of amorphous production confidential.

NOTE: Previous to 1909 Alabama and Alaska products were erroneously classed as "amorphous" instead of crystalline. After 1909 production of Georgia slates containing only 2 to 15 per cent graphitic carbon no longer recorded.

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Because of the limited number of producers in most years it is impossible to publish figures showing the output by States. Crystalline graphite, however, is produced principally in Alabama and Texas and to a lesser extent regularly in California and Montana. New York and Pennsylvania have produced extensive quantities in the past and are still potential producers, and in 1928 New Jersey again entered the list of producing States and may become an important factor in the supply of flake. Amorphous graphite is mined fairly regularly in Michigan, Nevada, and Rhode Island and has been produced also in Colorado, Wisconsin, Georgia, and North Carolina. As has been noted, the Georgia product consisted almost exclusively of carbonaceous shale and hence has not appeared in the statistics as graphite since 1909.

Crude graphite, both of domestic and of foreign origin, is often ground and further cleaned in special refining plants. There were 10 crucible-manufacturing concerns in the United States in 1928, but only one or two of them have any pulverized graphite to sell. This grinding is confined to cleaning and refining the material for their own use, and they make as little dust as possible. There are four graphite paint mills, and a much larger number of firms produce foundry facings. Only three or four firms produce a general line of graphite products, such as pencil graphite, lubricants, brushes, etc. Graphite is always ground dry, even for the paint trade. Ball or pebble mills are used merely for pulverizing, but when a lustrous product is required French buhr mills or emery mills which do not destroy the flake are employed. The United States Census Bureau figures covering graphite grinding and refining are as follows:

Production of ground and refined graphite

[The extraction from the ore and the refining of graphite (plumbago or black lead)]

	1927	1925	1923	1921	1919
Establishments	13	11	8	11	24
Wage earners (aver.)	289	228	244	152	497
Horsepower	3,011	2,927	2,700	1/	7,445
Wages	$ 340,510	$ 278,224	$ 304,437	$ 185,468	$ 434,317
Cost of materials	$1,319,161	$1,328,188	$1,062,018	$ 703,441	$1,092,684
Value of products 2/	$2,931,584	$2,569,487	$2,184,609	$1,456,864	$2,239,587
Value added by manufacture	$1,612,423	$1,241,299	$1,102,591	$ 753,423	$1,146,903

1/ No data.

2/ Includes values of miscellaneous products, normally belonging to other industries, made as secondary products by establishments engaged primarily in the production of ground and refined graphite (1925, $16,429; corresponding amounts for earlier years not calculated). Graphite is produced to a considerable extent by establishments classified in other industries, but the value of graphite thus made outside the industry can not be shown without the possibility of disclosing operations of individual establishments.

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Of the 13 establishments in 1927, two each were situated in Illinois, Michigan, New Jersey, and Pennsylvania and one each in Alabama, California, New York, Ohio, and Texas.

Artificial Graphite

Artificial or manufactured graphite has been produced in the United States since 1897 almost exclusively by one company, the Acheson Graphite Co. at Niagara Falls, N. Y. Figures of production were published regularly by permission of this company until its financial control passed to other hands in 1928. Formerly the available production data covered electrodes and other graphitized products, but in 1915 and subsequently they relate only to the grades of manufactured graphite which compete directly with natural graphite.[24] The value of the output has not been available for publication since 1914. No statistics are available for the small amounts of by-product graphite sold by carborundum and certain chemical manufacturers.

24 According to Moody's Manual of Industrials for 1927 the annual output of the Acheson Graphite Co. was about 45,000,000 pounds of graphite in powdered and electrode form.

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Artificial Graphite Production in the United States, 1897-1927

(Data from Mineral Resources of the United States.)

Year	Pounds	Value (dollars)	Value per lb. (cents)
1897	162,382	$ 10,149	6.25
1898	185,647	11,603	6.25
1899	405,870	32,475	8.00
1900	860,750	68,860	8.00
1901	2,500,000	119,000	4.76
1902	2,358,828	110,700	4.69
1903	2,620,000	178,670	6.82
1904	3,248,000	217,790	6.70
1905	4,591,550	313,980	6.83
1906	5,074,757	337,204	6.64
1907	6,590,000	481,239	7.30
1908	7,385,511	502,667	6.80
1909	6,664,017	480,000	7.20
1910	13,149,100	945,000	7.20
1911	10,144,000	664,000	6.55
1912	12,896,347	830,193	6.44
1913	13,633,342	973,397	7.14
1914	10,455,139	698,800	6.68
1915 1/	5,084,000	(2)	(2)
1916	8,397,281	(2)	(2)
1917	10,474,649	(2)	(2)
1918	9,182,272	(2)	(2)
1919	8,163,177	(2)	(2)
1920	7,399,749	(2)	(2)
1921	5,888,000	(2)	(2)
1922	13,031,926	(2)	(2)
1923	26,761,015	(2)	(2)
1924	10,986,192	(2)	(2)
1925	12,135,655	(2)	(2)
1926	21,163,986	(2)	(2)
1927	12,257,239	(2)	(2)

1/ Previous to 1915, figures included electrodes, etc.
2/ Values not available for publication.

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Secondary Graphite

In addition to the natural graphite and the artificial graphite produced in the United States there have been sporadic attempts to recover graphite from used crucibles and from kish. Even during the war period production from such sources was extremely small in the United States, although abroad, particularly in Germany and Austria, the business of recovering graphite and grog from old crucibles has attained the rank of an established, though rather small, industry. In Canada, also, old crucibles were treated in 1918 by a flotation process which recovered the graphite.

IMPORTS

The imports of graphite in the United States since 1900 have ranged from a minimum of 8,183 short tons in 1921 to a war-time maximum of 42,930 short tons in 1916. For the five-year period, 1923 to 1927, the annual average was 17,439 short tons, valued at $697,039, as compared with the pre-war average for 1909 to 1913, inclusive, of 24,345 short tons, valued at $1,808,382. It will be noted that although the reduction in quantity was only 28.4 per cent the value decreased by 61.7 per cent. The lower average value was due in part to lower prices, notably in 1923 and 1924, but more particularly to changes in the nature of the imports. Previous to 1914, by far the bulk of the imports was of Ceylon graphite, but more recently the decline in crucible manufacture has resulted in a smaller use of the more expensive Ceylon grades and a somewhat larger employment of the cheaper flake and amorphous grades.

Graphite imported for consumption into the United States, all varieties, 1901-1927

Year	Short Tons	Value	Year	Short Tons	Value
1901	16,044	$ 895,010	1916	42,930	$7,279,884
1902	20,385	1,168,554	1917	42,577	8,961,988
1903	17,928	1,207,700	1918	19,498	3,092,475
1904	14,195	905,581	1919	26,626	2,978,096
1905	17,457	983,034	1920	21,095	1,711,312
1906	25,487	1,554,212	1921	8,183	452,076
1907	22,939	1,777,389	1922	12,488	473,046
1908	11,456	762,367	1923	19,434	614,119
1909	21,267	1,854,459	1924	16,375	399,511
1910	25,235	1,872,592	1925	17,768	826,410
1911	20,702	1,495,729	1926	16,166	921,233
1912	25,643	1,709,337	1927	17,452	723,923
1913	28,879	2,109,791	1928	17,569	801,559
1914	21,990	1,398,209			
1915	23,075	2,241,163			

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Since the Tariff Act of 1922, which placed graphite on the dutiable list, import statistics are available separately for the different grades as follows:

Graphite imported for consumption into the United States, 1923-1928, by kinds.

Year	Amorphous		Crystalline lump, chip, or dust		Crystalline flake		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1923	11,252	$149,831	7,243	$426,417	939	$37,871	19,434	$614,119
1924	10,936	113,751	3,998	197,867	1,441	87,893	16,375	399,511
1925 1/	9,210	143,750	5,904	389,242	2,654	293,418	17,768	826,410
1926 1/	8,250	161,564	5,258	433,848	2,658	325,821	16,166	921,233
1927 1/	9,559	146,881	6,116	390,822	1,777	186,220	17,452	723,923
1928 1/	7,699	107,936	7,143	452,424	2,727	241,199	17,569	801,559

1/ Imports of graphite crucibles were not separately classified until 1925, when 3,100 crucibles, valued at $548, were reported (weight not recorded). Corresponding imports for 1926 were 9,513 crucibles, valued at $11,780, and for 1927, 2,583 crucibles, valued at $1,812; and for 1928, 2,368 crucibles, valued at $1,245.

According to an unpublished compilation made by the United States Tariff Commission from Department of Commerce records, covering the period September 22, 1922, to December 31, 1927, Mexico furnished 64 per cent of the imports of amorphous graphite; Ceylon supplied more than 90 per cent of the lump, chip, and dust; and Madagascar and France supplied almost 75 per cent of the total crystalline flake. Some of the imports from European countries are merely transshipments, but there is also a considerable quantity of refined graphite, originating in other countries but cleaned, sized and, perhaps, otherwise advanced in condition by finishing mills in England and Germany and to some extent in France.

Since Mexican graphite usually comes wholly from American-owned mines in Sonora it passes through Arizona ports of entry on its way to the plant of the U. S. Graphite Co. in Saginaw, Mich. or to New York or Pennsylvania. Japanese (probably Korean) imports are entered both at San Francisco and New York, while the imports of Italian amorphous in 1927 and 1928 was received at Galveston. Ceylon grades are generally distributed from New York, and the same is true of the Madagascar flake. Canadian flake goes mostly by rail to consuming points near the border, though some of it is entered at North Atlantic ports.

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Imports for consumption by countries and classes, September 22, 1922 to December 31, 1927, inclusive.
(Compiled from Department of Commerce Records by the United States Tariff Commission)

Country	Amorphous			Lump, chip and dust			Crystalline flake			Total		
	Quantity (pounds)	Value	Average price per pound (cents)	Quantity (pounds)	Value	Average price per pound (cents)	Quantity (pounds)	Value	Average price per pound (cents)	Quantity (pounds)	Value	Average price per pound (cents)
Canada	12,864,010	$243,536	1.89	1,579,909	$ 63,210	4.00	3,167,371	$194,286	6.13	17,611,290	$ 501,032	2.85
Mexico	64,919,861	250,889	.39	- - -	- - -	- -	- - -	- - -	- -	64,919,861	250,889	3.87
Greenland	134,400	600	.45	- - -	- - -	- -	- - -	- - -	- -	134,400	600	.45
Austria	10,468	180	1.72	117,518	1,364	1.16	- - -	- - -	- -	127,986	1,544	1.21
Denmark	- - -	- - -	- -	2,306	50	2.17	- - -	- - -	- -	2,306	50	2.17
Germany	70,949	2,822	3.98	1,846	217	11.76	241,867	13,922	5.76	314,662	16,961	5.39
Italy	2,519,419	28,338	1.12	154,092	2,026	1.31	- - -	- - -	- -	2,673,511	30,364	1.13
Norway	- - -	- - -	- -	28,569	2,078	7.27	2,035	61	3.00	30,604	2,139	7.00
Switzerland	66,678	4,015	6.02	- - -	- - -	- -	- - -	- - -	- -	66,678	4,015	6.02
United Kingdom	159,243	7,996	5.02	154,940	10,364	6.69	1,062,828	58,419	5.50	1,377,011	76,779	5.58
France	386,967	8,759	2.26	691,052	40,831	5.91	10,546,668	514,725	4.88	11,624,687	564,315	4.85
Madagascar	684	45	6.58	263,890	7,092	2.69	3,635,296	140,612	3.87	3,899,870	147,749	3.78
Aden	397,013	2,991	.75	- - -	- - -	- -	- - -	- - -	- -	397,013	2,991	.75
Morocco	- - -	- - -	- -	- - -	- - -	- -	84,269	4,529	5.37	84,269	4,529	5.37
British India	203,168	6,852	3.37	2,128,381	66,954	3.15	64,987	887	1.36	2,396,536	74,693	3.12
Ceylon	1,718,192	48,273	2.81	55,903,638	1,721,902	3.08	- - -	- - -	- -	57,621,830	1,770,175	3.07
Siam	- - -	- - -	- -	112,336	2,929	2.61	- - -	- - -	- -	112,336	2,929	2.61
French Indo-China	- - -	- - -	- -	- - -	- - -	- -	4,630	173	3.74	4,630	173	3.74
Java and Madura	- - -	- - -	- -	122,587	4,041	3.30	- - -	- - -	- -	122,587	4,041	3.30
China	506,730	3,913	.77	- - -	- - -	- -	209	8	3.83	506,939	3,921	.77
Japan (incl. Chosen)	16,688,429	134,524	.81	- - -	- - -	- -	- - -	- - -	- -	16,688,429	134,524	.81
Warehouse 1/	478,411	2,921	.61	197,120	7,947	4.03	122,079	3,655	2.99	797,610	14,523	1.82
Total	101,124,622	746,654	.74	61,458,184	1,931,005	3.14	18,932,239	931,277	4.92	181,515,045	3,608,935	1.99

1/ Country of origin not recorded.

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TARIFF DUTIES

Under the name of plumbago, graphite was on the free list from 1872 to 1922 when, under the Fordney-McCumber Tariff Act it was made dutiable under paragraph 213, which reads as follows:

> "Graphite or plumbago, crude or refined: Amorphous, 10 per centum ad valorem; crystalline lump, chip, or dust, 20 per centum ad valorem; crystalline flake, 1½ cents per pound. As used in this paragraph, the term 'crystalline flake' means graphite or plumbago which occurs disseminated as a relatively thin flake throughout its containing rock, decomposed or not, and which may be or has been separated therefrom by ordinary crushing, pulverizing, screening, or mechanical concentration process, such flake being made up of a number of parallel laminae, which may be separated by mechanical means."

It is a rule of customs procedure that commercial classification holds as against technical or scientific nomenclature. Most Canadian deposits, for example, have been described by geologists and engineers as composed of crystalline flake, but the dust therefrom has been entered into the United States as amorphous graphite under a ruling of the Customs Court.[25] The abstract of the evidence reads in part as follows:

> "The importer produced six witnesses who all qualified as experts and who all testified that the merchandise in question was amorphous graphite and that amorphous graphite had a well-known and uniform commercial designation at and prior to September 21, 1922. They all testified that the merchandise was not crystalline, although traces of crystalline were found therein. At least one witness testified that there was some crystalline present in all amorphous graphite."

EXPORTS

In view of the fact that a large proportion of the domestic supply of graphite is imported it is rather surprising to note that there are quite substantial exports of unmanufactured graphite as well as of sundry graphite products. The moderately high unit value of the unmanufactured graphite exported, ranging from 6 to 8 cents per pound in recent years, suggests a refined product. A personal canvass of the exporters indicates that virtually all this material is finely powdered graphite, especially prepared for the manufacture of pencils. Most of it is Mexican graphite, either used alone or blended with a little Ceylon or other graphites. Pencil graphite ground in American mills is largely used in Nuremberg and other European pencil-making centers and goes as far even as Madras, India. Rather small amounts of powdered graphite are exported for use in paints, lubricants, electric brushes, and dry cells.

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25 Treasury Decision 40660, Feb. 4, 1925.

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Graphite exported from the United States, 1912-1927

Year	Unmanufactured graphite		Manufactures of graphite	Year	Unmanufactured graphite		Manufactures of graphite
	Short tons	Value			Short tons	Value	
1912	2,320	$383,458	$ 177,082	1920	607	$112,771	$610,261
1913	2,692	391,906	238,302	1921	921	95,998	679,359
1914	1,960	277,386	215,878	1922	569	78,094	1/ 255,019
1915	529	52,583	536,572	1923	908	138,542	1/ 335,778
1916	798	98,118	1,339,259	1924	1,022	144,108	1/ 250,957
1917	2,573	349,563	891,687	1925	945	142,122	1/ 337,481
1918	954	121,555	731,518	1926	405	49,235	1/ 463,084
1919	629	90,185	788,755	1927	2/ 1,819	2/435,997	2/

1/ Exclusive of crucibles, figures for which are no longer available since they are included in the classification "Crucibles, clay and graphite." Exports under this latter classification were 408,249 crucibles, valued at $91,699 in 1925; 618,735 crucibles, valued at $149,456 in 1926; and 558,000 crucibles, valued at $108,857 in 1927.

2/ Classification changed in 1927 to "Graphite and manufactures, except crucibles."

Exports of pencils and pencil leads (including refillable pencils) are not included in the above figures, but are recorded separately as follows:

Value of pencils and pencil leads exported from the United States, 1918-1927

Year	Value	Year	Value
1918	$2,497,208	1923	$1,636,417
1919	3,565,347	1924	1,641,895
1920	3,849,221	1925 1/	2,186,772
1921	2,074,508	1926 1/	2,144,614
1922	1,355,736	1927 1/	1,907,972

1/ Includes refillable pencils. In 1927 the exports of "refillable pencils and pencil leads" were given separately, amounting to $711,438.

MARKET GRADES

There are no widely accepted exact standards for the different grades of graphite. Sales are always based either upon actual samples submitted or upon the long-established reputation of individual dealers. Mexican graphite enjoys a large share of the better-class pencil business. Ceylon lump and chip are used mainly for crucible manufacture; and lubricating graphite has to be free from grit that would injure bearings. Except for a few such generalizations there is no definite means of classification according to use, two or more quite different grades often being used interchangeably for the same purpose. Every canvass of

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the trade serves only to confirm the fact that conflicting opinions exist not alone among producers and dealers who might be expected to extol the advantages of their own brands but also among consumers whose interest is simply to secure the maximum service from their finished products.

The graphites of commerce contain various impurities, the graphitic carbon content varying from as low as 30 or 35 per cent for the paint trade up to a maximum of 90 or 95 per cent. Some of the amorphous graphite mined in the United States has been nothing more than shale or slate containing only enough carbonacecus matter to make it black. Other qualities grade into anthracite. Usually it is the physical character of the product that is of utmost importance, and the value of crystalline graphite depends upon its structure and upon the size of the particle quite as much as upon its carbon content. Flake finer than 90- or 100-mesh, for example, is not acceptable to crucible makers, and much larger flake (up to about 12-mesh) is desired, particularly for large crucibles. However, domestic flake is also graded according to its graphitic carbon content, thus No. 1, contains 88 per cent of graphitic carbon; No. 2, 82 to 88 per cent; and inferior flake, 82 per cent.[26]

Madagascar exports now consist to a large extent of "Standard No. 1 flake," containing 85 per cent of graphitic carbon and sized so as mostly to pass 20-mesh and remain on 60-mesh. Efforts are made by the French Government to hold all producers to this standard.

Ceylon graphite is sometimes graded as follows:

Lump. Ranging from the size of walnuts down to that of a pea. Ordinarily runs about 90 per cent carbon.

Chip. From the size of a pea to a little smaller than wheat grains.

Dust. Often described as comparable in size to gunpowder, or from 40- to 60-mesh. Contains from 55 to 80 per cent carbon.

For each of the various classes two grades are recognized, and formerly there were three. A specially refined quality, called needle lump because of its more or less fibrous structure, is likewise produced and sold at a substantial premium over the price of even No. 1 lump. There is also a variety of lump described as large lump (1 to 3 inches) which, although it contains 96 to 99 per cent of graphitic carbon, has not the structure desired for making crucibles and usually sells for a lower price than crucible lump. In addition to the above, flying dust, comprising particles too small to be classed as ordinary dust, is separated and sold.

26 Alabama operators have recommended the classification: No. 1, 90 per cent plus; No. 2, 82 per cent plus; and inferior, 80 per cent plus.

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Amorphous graphite is graded according to the locality from which it comes. Each deposit has its local peculiarities. In the crude state it ranges in size from about half-inch down to dust, very much like slack.

Graphite is sold on the basis of net weight, the tare of the containers being always deducted. Ceylon graphite is packed in 600-to 700-pound (net) casks but recently due to the high cost of casks even lump has come in bags, 333 of which contain 25 tons (that is, about 167 pounds each). The tare of the casks is 65 pounds and of the bags 2 pounds, each. Madagascar graphite is shipped in heavy double jute bags, weighing about 220 pounds each, and domestic is marketed usually in 150-pound sacks. Mexican crude amorphous is shipped in bulk in box cars; Korean graphite, on the other hand, comes in rather small barrels, containing about 375 to 400 pounds each.

DISTRIBUTION OF CONSUMPTION

The relative importance of the various outlets for graphite has undergone great changes within the last few years. Before the World War graphite crucibles accounted for more than 50 per cent of the quantity and probably 75 per cent or more of the value of all graphite consumed in the United States; but by 1923 the proportion used in crucibles had dropped to about 15 per cent and subsequently it has declined even further. This decline is due to the fact that changes in the methods of melting both high-grade steels and brass have reduced the demand for crucibles. With respect to steel the extent of this reduction is indicated by the figures for production of crucible steel, which averaged 107,000 tons yearly during the four-year period immediately preceding the outbreak of the World War and only 25,000 tons annually during the period 1923 to 1926. Since similar changes have taken place in the brass industry the consumption of high-grade graphite for crucible manufacture is scarcely one-third as great now as it was in 1913. At present almost all firms that melt steel or brass in large quantities are using electric furnaces or gas-fired hearth furnaces. It is possible now to get a small electric furnace for as little as $35,000, and if one of these furnaces can be kept busy it is usually more economical than to continue the use of crucibles. Crucible melting is now confined to small or intermittent operations. Since it appears that all firms that can use electric furnaces economically are now using them further inroads upon the demand for crucibles from this source can not continue at the former rate. Nevertheless, a further decline in the demand for crucible graphite is expected, because there is a tendency to centralize manufacture in large plants and because crucibles that are being made to-day last longer and hence need not be replaced as frequently as those formerly employed. The trend toward the use of larger crucibles likewise tends to decrease the ratio of graphite required to metal melted.

On the other hand, foundry facings, though formerly constituting only 10 per cent of domestic production recently have accounted for more than one-half the total. Further increases in this field tend to be checked by a larger use of sand blasting for cleaning castings as well as by the competition of other facing materials and the larger use of die-casting.

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Dry-cell manufacture, formerly an almost insignificant factor in demand, has now become one of the leading outlets. A larger admixture of graphite is now used in the manufacture of cells and there has been a tremendous expansion in the number of cells produced both for flashlights and for radio work.

The more important changes that have taken place in the trade are indicated roughly by the following estimates which have been made at various times:

	1913 1/	1919 1/	1924 2/
	Per cent	Per cent	Per cent
Crucibles	55	45	13
Foundry facings	10	25	52
Lubricants	5	10	1
Pencils and paints	10	5	23
Stove polish	15	5-10	1
Other uses	5	10- 5	10
	100	100	100

1/ Estimates by U. S. Geological Survey.
2/ Based on canvass by U. S. Tariff Commission.

Since the total consumption has remained virtually stationary in recent years the per capita consumption of graphite is declining. In the last few years the only net advances appeared to be in the demand for making dry cells. Among the older uses there has been some increase in the requirements for zinc retorts, lubricants, and pencils and crayons, and there has been a decided increase in the requirements for ladle stoppers, foundry facings, and commutator brushes -- particularly the graphite brushes used in automobile starters -- but these increases have been insufficient to offset the drastic falling off in the demands of crucible makers.

The effect of these changes is not reflected so much in the aggregate tonnage as it is in the value. Because of the reduced demand for the more expensive crucible grades of graphite the proportion of crystalline graphite declined from 32 per cent of the total domestic consumption before the war to only about 20 per cent in 1926. Meanwhile the demand for artificial graphite has grown substantially. Within the crystalline field itself the demand for the more expensive Ceylon graphites had declined and the use of the cheaper kinds of flake has relatively increased.

PRICES

As a result of the World War the prices of graphite advanced to two or three times pre-war figures; later, due to congestion of stocks, they receded sharply, remaining substantially under the pre-war level for several years after the armistice. During 1925 the New York price became stabilized at approximately pre-war figures, but this recovery was attributable in large part to the fact

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that imports of graphite became subject to duty in 1922, whereas previously they had been for many years on the free list.

It should be remembered that because of the great number and variety of grades the graphite market is an intricate structure of specialty transactions. Moreover, since each sale is generally consummated by individual bargaining between buyer and seller the market for even one grade is rather difficult to appraise. In the United States each dealer maintains for his own guidance a nominal schedule of prices made up to conform with his own special sources of supply and in accordance with his expectations of demand, but such schedules are fairly flexible, and even in the first instance they are not based upon any established series of differentials or premiums between different grades. Even on the same date the same type of graphite may be quoted at materially different prices by different dealers or to different consumers. Buying connections, knowledge of market conditions, and less tangible factors influence the price the buyer has to pay quite as much as does the size of the order he wishes to fill. To a person accustomed to the narrow ranges of most metal and ore markets the diversity of the graphite market appears complicated if not bewildering. Actually it is possible to make a fairly accurate approximation of average prices on a specific date but it is almost impossible to follow the market in detail over a period of years. Within the last few years quotations have appeared in the trade journals relative to some 25 different grades of graphite, but scarcely any of these quotations can be followed for more than short intervals. Average prices of various qualities of Ceylon graphite are summarized in an accompanying table, but even the Ceylon figures for later years are not quite comparable with those for former years, owing to the fact that three grades were ordinarily quoted for each class before the war whereas more recently the number has been reduced to two. Efforts have been made to standardize the Madagascar graphite, and eventually it may be possible to use this graphite as a rough index of the market; but in the past lack of uniformity has characterized the output of most countries, other than Ceylon, from which American supplies have been drawn. Domestic production especially has been sporadic and the product has been notoriously variable in quality. Moreover, a considerable portion of it being contributed by concerns that work up the mine product in their own factories, has not come upon the market except as finished products.

In a general way the best Ceylon lump may be taken as a barometer of the market. Before the war this grade sold generally at 8 cents to 10 cents per pound delivered in New York. After rising to a maximum of 32 cents during the war it dropped to below 6 cents in 1921 where, despite the new tariff, it remained until late in 1924 when it rose slowly to 7 cents. Since early in 1925 the prices remained quite steady within the range of 7½ cents to 9½ cents. Ceylon chip normally sells about 1 to 2 cents less per pound than lump. On an average Ceylon dusts bring a price that is approximately one-third less than the price of lump, but there is no fixed relationship. Dust represents the screenings of larger sizes, and being a by-product it may be sold for a low price when there happens to be a large accumulation or it may fetch a relatively high price when stocks are low. In recent years imports of dust have been fairly important, amounting to approximately one-fourth of the total imports of Ceylon graphite.

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Toward the end of 1928 No. 1 crucible lump was worth about 8¼ to 9¾ cents per pound c.i.f. New York duty paid. No. 2 crucible lump was worth a maximum of about 7½ cents. Other kinds of Ceylon lump, some of them containing actually more carbon but lacking the structure most desired by crucible makers, were obtainable for 6½ cents per pound and even less, or somewhat less than crucible chip. One quality containing up to 92 per cent graphitic carbon but rather dull in appearance could be obtained for 5 cents per pound. Low-grade dust, containing 55 per cent graphite, was quotable at 2½ cents per pound c.i.f. New York; 65 per cent dust was worth from 2¼ to 3 7/8 cents; and a high-grade dust was selling for as much as 5 cents per pound or for almost the same price as Madagascar flake.

Average prices of Ceylon graphite, c.i.f. New York in cents per pound, 1911-1927

	Ceylon lump		Ceylon chip		Ceylon dust	
Year	First grade	Second grade	First grade	Second grade	First grade	Second grade
1911	8¼- 9	7 - 8	5¼- 5¾	4 - 5	3½- 4	2¾- 3¼
1912	8¼-10	7 - 8	5¼- 7	4½- 6	3 - 3½	2½- 2¾
1913	9½-11	7½- 9	7½-10	6½- 8½	4 - 5½	3 - 4
1914	6½- 9½	7½- 8½	7¼- 7¾	6½- 7	4¾- 5¼	3½- 4
1915	9 5/8-20	8 -14	7 -14	6½-12	7½- 9½	6½- 9½
1916	20 -28	14 -21	13½-20	11½-17	9½-12	9½-10
1917	28 -32	21 -23	20 -23	17 -19	11 -13	10 -12
1918	15¼-28½	14 -22	12½-21½	11 -18½	10½-12	9 -10
1919	14 -15¼	12 -13	10½-11	8 - 9	6¾- 7½	5 - 6
1920	9 -14	7 -11	7 -10	5½- 7½	5 - 7	3½- 5
1921	5½- 6	4½- 5	4½- 5	3½- 4	3¼- 3¾	2 - 2½
1922	5 - 6	4 - 4½	3¾- 4¼	3¼- 3¾	3 - 3½	2 - 2½
1923	5 - 6	4 - 4½	3¾- 4¼	3¼- 3¾	3 - 3½	2 - 2½
1924	5½- 7	4½- 6	4 - 6	3½- 5	3¼- 4½	2 - 3
1925	7½- 9½	6½- 8½	6½- 7½	5½- 6½	3½- 5½	3 - 4½
1926	7½- 9½	6½- 8½	6½- 7½	5½- 6½	3½- 5½	3 - 4½
1927	7½- 9½	6½- 8½	6½- 7½	5½- 6½	3½- 5½	3 - 4½
1928	7½- 9½	6½- 8½	6½- 7½	5½- 6½	3½- 5½	3 - 4½

Madagascar graphite is quotable on the basis of a 85 per cent standard grade established by the French Government. It is all bought through Marseilles. Due to uneven quality and the difficulty of introducing a new product Madagascar flake for some years did not command the relative position that it now holds as compared with the best No. 1 domestic flake despite the fact that its flaky particles are somewhat larger and thicker. The armistice came while large stocks were accumulating in Madagascar, and in 1921 some portions of these stocks could be purchased on the island for 1½ cents or less per pound. Subsequently the price rose to 1,050 francs per ton and still later to 1,900 francs per metric ton laid down at Tamatave warehouse. When the franc was worth 3 cents the latter price was equivalent to 2.6 cents per pound, increasing to 3.4 cents when exchange was stabilized at 3.9 cents. In December, 1928, the New York price was from $125 to $135 per long ton (averaging 5.8 cents per pound) including ocean freight amounting to about $18 per ton and the duty of 1½ cents per pound in addition to other

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charges and importer's profits. The 80 per cent grade, though somewhat cheaper in Madagascar, was quoted at only a slight reduction from the price of the standard grade.

Madagascar flake was for a time quoted weekly in London in pounds sterling per long ton. Monthly averages of these prices converted at current exchange and reduced to cents per pound show an increase from 2.9 cents per pound in July, 1924, to 6.3 cents per pound in July, 1925, declining to 6.0 cents in September of the same year. In the New York market the pre-war price of Madagascar No. 1 flake was 4 to 5 cents per pound. The trend in recent years is indicated by the following simple averages of monthly quotations as reported by the Engineering and Mining Journal (New York):

Year	Cents per lb.
1923	4.5
1924	5.2
1925	7.2
1926	7.3
1927	7.0
1928	7.2

Domestic flake must in general find its market in competition with the somewhat better standardized products of other countries. A tabulation of domestic prices before the war (1912) listed the following: Best crucible flake, 5½ cents to 7½ cents per pound; medium crucible flake, 4 cents to 6½ cents; inferior flake, 2½ cents to 4 cents; and dust ¾ cents to 3 cents. In 1917, No. 1 domestic flake was quoted, according to quality, at 12 cents to 18 cents; No. 3 flake at 6 cents to 10 cents; and dust at ½ cent to 5 cents.[27] In 1920 and 1921, during the depression, No. 1 flake could be sold only with difficulty, and there was no outlet whatsoever for inferior grades. Nominally this situation improved gradually until in 1928 (July) No. 1 flake was quoted at 10 cents and upwards; No. 2 at 7 cents and up, and foundry facings and other finely grained crystalline or amorphous qualities at 3 cents per pound and upwards. In December, 1928, No. 1 domestic flake was actually sold in consuming markets at 6-1/8 cents per pound; No. 2 flake was quotable at 5 cents, although apparently there were no sales; and No. 3 and No. 4 dust were both selling for 2.8 cents delivered at foundry-facing manufacturers' plant.

Canadian flake ordinarily sells for about the same price as domestic. According to Canadian Government reports the price increased during the war from about 5 cents per pound in 1914 to 16 cents in 1918, dropping early in 1919 to 10 cents. Recently a part of the Canadian product has been sold as amorphous and this classification, although contrary to the usual technical classification of this material (it is rather a small crystalline flake), has been accepted for purposes of customs classification.[28]

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27 Figures taken largely from Mineral Resources of the United States (annual chapters).

28 See footnote 25.

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Amorphous graphite is usually sold by the ton. Korean products containing 80 to 85 per cent of graphitic carbon cost $20 to $25 per ton delivered in New York before the war and rose to $40 and later to $60 in 1917, but finally dropped to $25 or only a trifle more than the pre-war price. At the end of 1928 the ordinary commercial grade, 83 to 85 per cent of carbon, was worth approximately $38.75 per ton c.i.f. New York, duty paid. A better quality, obtained only in limited quantities, was quoted nominally at a premium of $4 or $5 a ton higher. A low grade (75 to 80 per cent) was worth $30 to $32 per ton. This latter grade is harsh and gritty and rather difficult to break with the fingers; it resembles anthracite in some respects and is sold only to foundry-facing and paint manufacturers. Mexican graphite usually has been a trifle more expensive than Korean, the crude product selling for $30 a ton in 1910. Since the war the price of crude Mexican at New York has been quoted nominally at 1¾ cents per pound which is equivalent to less than pre-war prices. In December, 1928, the price in Philadelphia or New York was $40 to $50 per ton in carload lots. This includes $16 or $17 railroad freight as well as duty and other charges. The price f.o.b. Sonora was about $16. The bulk of the Mexican material is sent to Saginaw, Mich., where it is ground or otherwise prepared before being sold. After passing through finishing mills the well-prepared product is sold by the pound, often fetching as much as 5 cents or practically as much as a medium good flake graphite. The Rhode Island product, in paper bags, has been quoted since 1923 at $20 to $22.50 per ton in New York City and as low as $18 per ton nearer the mine. In the crude state the price has ranged recently from $10 to $12 per ton.

Pre-war prices for artificial graphite ranged from 4 cents to as much as 28 cents per pound for the powdered variety according to grade. For graphitized electrodes the prices remained between 10 cents and 12 cents per pound. In general artificial graphite competes in price with amorphous and the various kinds of crystalline dust, all of which sell for between 2 and 3 cents per pound.

Since published quotations are more or less fragmentary information as to the average prices of many imported varieties of graphite can best be obtained currently through the medium of the import statistics. Such importers as operate finishing mills maintain substantial stocks, but enough of the import business is transacted on a straight brokerage basis so that the cost of graphite to the largest American consumers is simply the foreign price, f.o.b. port of shipment, plus freight, landing charges in New York, duty, and importer's profit, which on cheaper grades amounts to 2 to 10 per cent of the purchase price and on Ceylon lump or chip to about one-half cent per pound. The ocean freight on the various kinds of graphite, as of December, 1928, are approximately as follows:

From	Per gross ton
Ceylon	$6.10
Madagascar	17.90
Marseilles	3.00
Korea	9.76
Mexico (rail)	16.00

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